Medication Dosing Errors in Pediatric Patients Treated by Emergency Medical Services

John D. Hoyle, Jr., MD, Alan T. Davis, PhD, Kevin K. Putman, EMT-P, Jeff A. Trytko, MS, William D. Fales, MD

Abstract

Bakground. Medication dosing errors occur in up to 17.8% of hospitalized children. There are limited data to describe pediatric medication errors by emergency medical services (EMS) paramedics. It has been shown that paramedics have infrequent encounters with pediatric patients. **Objective.** To characterize medication dosing errors in children treated by EMS. **Methods.** We studied patients aged ≤11 years who were treated by paramedics from eight Michigan EMS agencies from January 2004 through March 2006. We defined a medication dosing error as ≥20% deviation from the weight-appropriate dose, as determined by the patient's reported weight in the prehospital medical record or by use of the Broselow-Luten tape (BLT). We studied errors in administering six EMS medications commonly given to children: albuterol, atropine, dextrose, diphenhydramine, epinephrine, and naloxone. **Results.** There were 5,547 children aged ≤11 years who were treated during the study period, of whom 230 (4.1%) received drugs and had a documented weight. These patients received a total of 360 medication administrations. Multiple drug administrations occurred in 73 cases. Medication dosing errors occurred in 125 of the 360 drug administrations (34.7%; 95% confidence interval [CI] 30.0, 39.8). Relative drug dosage errors (with 95% CI) were as follows: albuterol 23.3% (18.4, 29.1), atropine 48.8% (34.3, 63.5), diphenhydramine 53.8% (29.1, 76.8), and epinephrine 60.9% (49.9, 73.9). The mean error (± standard deviation) for intravenous/intraosseous 1:1000 epinephrine overdoses was 808% ± 428%. The mean error (± standard deviation) for intravenous/intraosseous 1:1000 epinephrine underdoses was 35.5% ± 27.4%. **Conclusions.** Medications delivered in the prehospital care of children were frequently administered outside of the proper dose range when compared with patient weights recorded in the prehospital medical record. EMS systems should develop strategies to reduce pediatric medication dosing errors. **Key words:** pediatric; medical errors; medications; emergency medical services; patient safety.

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Address correspondence and reprint requests to: John D. Hoyle, Jr., MD, Helen DeVos Children's Hospital/Michigan State University College of Human Medicine, Emergency Department, MC 49, 100 Michigan Street NE, Grand Rapids, MI 49503. e-mail: jdhoyle@hotmail.com

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Introduction

Medication errors occur in the hospital setting and often contribute to patient morbidity and mortality. The 1999 Institute of Medicine report found that 7% of hospitalized patients are exposed to a serious medication error.[1] Children are particularly vulnerable to medication errors because drug dosages are calculated for body weight.[2] Medication dosing errors occur in up to 17.8% of hospitalized children.[2–9] Marino et al. demonstrated that errors of prescription, preparation, and administration occurred in up to one of every 2.3 medication orders on pediatric hospital units,[10] yet little is known about the prevalence of medication dosing errors in the prehospital setting.

Medication administration errors may be common in the prehospital setting. For example, one study found that the error frequency of epinephrine doses was 56%.[11] Paramedic encounters with children have been shown previously to be infrequent.[12,13] This results in little real-life practice with the drug calculations necessary to treat this patient group, and this limited experience can contribute to errors. Other potential explanations include inadequate training or retraining and lack of safety systems for error prevention. The administration of medication to children in the prehospital setting is particularly difficult since emergency medical services (EMS) personnel must estimate the child's weight, and then calculate, draw, and dispense correct dosages in an environment that is uncontrolled and frequently chaotic.

Relatively few studies characterize paramedic drug administration errors in children. The objective of this study was to determine the frequency and magnitude of medication dosing errors in children treated by paramedics and determine the frequency of medication dosing errors in patients for whom the use of the Broselow-Luten tape (BLT) was documented.

METHODS

Study Design

We conducted a retrospective analysis of children treated in the prehospital setting by paramedics. The paramedics were from eight EMS agencies in Michigan that contribute data voluntarily to an electronic administrative database. The Spectrum Health/Helen DeVos Children's Hospital Institutional Review Board (IRB) and the Michigan Department of Community Health IRB approved this study with waiver of informed consent.

Study Setting and Participants

The eight agencies that contribute to this administrative database serve a demographically diverse population encompassing both urban and rural settings in the northern, central, and southern regions of Lower Michigan. Based on 2000 U.S. census data,[14] these agencies provide service to approximately 10% of Michigan's population (1,009,500 persons) and care for approximately 4,700 pediatric (<18 years) patients annually.

The EMS agencies consisted of one-, two-, and three-tiered response systems. Ambulance crews consisted of either two paramedics (emergency medical technicians–paramedic [EMT-Ps]) or one EMT-P plus one basic EMT (EMT-B). The majority of the EMS systems were private, third-service agencies, with for-profit and not-for-profit systems both represented.

Study Protocol

We analyzed clinical EMS patient care data from the Michigan Emergency Records Management and Information Database (MERMaID), an administrative database of EMS patient encounters. Participation in MERMaID by EMS systems is voluntary. Data elements in MERMaID were modeled after National Highway Traffic Safety Administration standards for EMS data reporting and collection. MERMaID has data fields for all patient care–related activities, including patient demographics (age, race), run location (street/intersection, private residence, etc.), call priority, vital signs, weight, drug(s) administered, dose(s), intravenous (IV) access, treatments, and disposition. Drug doses are entered as free text. Each individual drug dose is entered as a separate dose. Provider information is also included. Paramedics enter patient care information directly into this database via computer during and after the patient encounter. The weight field accepts kilograms only and does not convert pounds to kilograms. MERMaID has been used previously for a large-scale pediatric continuous quality improvement project[15] as well as routine continuous quality improvement. We included data from January 1, 2004, to March 31, 2006.

Administrative databases have been previously used to identify errors in prehospital airway management,[16] decreased survival in cardiac arrest patients intubated in the field,[17] and minimal improvement in pain management for long-bone fractures in the emergency department (ED).[18] Our methodology paralleled that of Wang et al.[16]

Patient data were generated by queries to the MERMaID database. Once all required patient data had been obtained from queries, this information was exported into Access (Microsoft Corp., Redmond, WA), encrypted, and sent to the authors (JDH, ATD) for analysis. The data were then transferred to an Excel (Microsoft Corp.) spreadsheet. Specific parameters for an incorrect drug dose, including appropriate dose for weight, route of administration (e.g., IV vs. endotracheal [ET]), and drug concentration, were defined a priori by the study team (Table 1) from the Michigan Model Pediatric Protocols (MMPP). The MMPP were adapted from the National Association of EMS Physicians (NAEMSP) model pediatric protocols with input at the state level.[19] The MMPP were adopted and followed by all the agencies participating in this study. For the study period, MMPP included high-dose epinephrine for cardiac arrest. These parameters were programmed into the Excel database, which then identified errors. Any inconsistencies in the data were reviewed by two investigators (JDH, ATD) and discussed until consensus was reached. The investigators were not blinded to the purpose of the study. We included patients aged ≤11 years who were treated by EMS and who had a weight or Broselow-Luten tape (BLT) color documented in the prehospital record. We included only patients aged ≤11 years because the 50th percentile weight on the current Centers for Disease Control and Prevention (CDC) growth charts for males is equal to the last listed weight on the BLT of 36 kilograms.[20] We excluded patients with no weight or BLT color documented in the prehospital medical record, except for patients who received albuterol only, since its dose was the same for all children and not based on weight. The BLT is a color-coded measuring device that estimates a child's weight based on his or her length. It also provides weight-appropriate doses

Table 1. Definitions of Correct Drug Doses

Drug Name	Concentration	Route	Clinical Situation	Dose	Maximum Dose*
Epinephrine (first dose)	1:10,000	IV/IO	Vfib/Vtach/cardiac arrest	0.01 mg/kg	1.0 mg
Epinephrine (second & subsequent doses)	1:1,000	IV/IO	Vfib/Vtach/cardiac arrest	0.1 mg/kg	None
Epinephrine (first & subsequent doses)	1:1,000	ETT	Vfib/Vtach/cardiac arrest	0.1 mg/kg	None
Epinephrine (first & subsequent doses)	1:10,000	IV/ IO	Bradycardia	0.01 mg/kg	1.0 mg
Epinephrine (first & subsequent doses)	1:1,000	ETT	Bradycardia	0.1 mg/kg	None
Epinephrine (first dose)	1:10,000	IV/IO	PEA/asystole	0.01 mg/kg	1.0 mg
Epinephrine (second & subsequent doses)	1:1,000	IV/IO	PEA/asystole	0.1 mg/kg	None
Epinephrine (first & subsequent doses)	1:1,000	ETT	PEA/asystole	0.1 mg/kg	None
Epinephrine (first & subsequent doses)	1:1,000	SubQ	Anaphylaxis	0.01 mg/kg	0.3 mg
Epinephrine (one dose only)	1:1,000	SubQ	Bronchospasm	0.01 mg/kg	0.3 mg
Atropine	Standard	IV/IO	Bradycardia	0.02 mg/kg	0.5 mg
Albuterol	Standard	Neb	Anaphylaxis/bronchospasm	2.5 mg	2.5 mg per dose
Diphenhydramine	Standard	IV/IO/IM	Anaphylaxis	1.0 mg/kg	50 mg
Dextrose	D_{25} & D_{50}	IV/IO	Altered mental status/ seizure	0.5 g/kg	None
Naloxone	Standard	IV/IO	Altered mental status	0.1mg/kg	2.0 mg

*Numerical maximum doses are the doses listed in protocols. "None" indicates the maximum dose is based on the patient's weight.
D_{25} & D_{50} = dextrose 25% and dextrose 50%; ETT = endotracheal tube; IO = intraosseous; IV = intravenous; Neb = nebulizer; PEA = pulseless electrical activity; SubQ = subcutaneous; Vfib = ventricular fibrillation; Vtach = ventricular tachycardia.

for emergency drugs. All paramedics in the study had access to the BLT on their ambulances for patient treatment, but use of the BLT was not required. The versions of the BLT available were the 2002 and 2005 versions. Both of these included high-dose epinephrine. By statewide protocol, EMS providers could administer standard protocol dosages without making radio contact with a hospital base station.

Measurements

In this study, we examined errors in administering six common medications: albuterol, atropine, dextrose, diphenhydramine, epinephrine, and naloxone. We chose these medications because standard EMS protocols specify single-bolus administration of these drugs; these drugs are not titrated. Examples of excluded prehospital medications include diazepam, midazolam, and morphine. The EMS agencies in this study carried either 25% dextrose (D_{25}) or 50% dextrose (D_{50}). Those who carried D_{50} were required by protocol to dilute it to D_{25} prior to administration to children.

We defined a medication dose administration error as $\geq$20% deviation from the correct weight- or BLT-based dose. Previous ED studies have defined a medication dose error as a 10%–25% deviation from the correct dose.[4–7] Because there are no established definitions for medication dosing error in the prehospital setting, by study team consensus, a $\geq$20% deviation was chosen. It should be noted that Marcin et al. used 10% as the definition of error for epinephrine and atropine.[7]

Because of the difficulty in matching the prehospital record to hospital records across such a large number of hospitals, we did not grade these errors for harm. We used the documented weight/BLT color in MERMaID to determine whether a dose was correct. MERMaID allows for weight documentation as a kilogram value and/or a BLT color. For patients with a BLT color instead of weight, the dose listed for that color block (e.g., yellow) was defined as the correct dose. If a patient had both a weight and a BLT color documented in MERMaID, the dose associated with the BLT color was utilized as the correct dose for analysis. We compared the error frequency for patients for whom BLT use was documented in the prehospital medical record with that for patients for whom BLT use was not documented (not used), in an attempt to understand the impact of BLT use on error frequency. If a patient received multiple doses of the same medication, each incorrect dose was treated as a separate error.

For children with a documented BLT color who received diphenhydramine or epinephrine for anaphylaxis, which are not listed on the BLT, an administered dose associated with any of the weights on the patient's corresponding BLT color block was defined as correct. For example, the yellow block on the BLT contains the weights of 12–14 kg. For diphenhydramine and epinephrine for anaphylaxis, any dose given to a patient that corresponded to a dose for 12, 13, or 14 kg was counted as correct. For albuterol, which is not listed on the BLT, the correct dose for all ages was 2.5 mg according to the MMPP. Since albuterol did not require any calculations and had the same dose for all patients, regardless of weight or age, we were interested in how often an incorrect dose was documented.

We determined the characteristics of the population, including service type (scene, transfer, etc.), location type (street, residence, etc.), patient age, gender, race, and ethnicity, insurance type, patient weight or BLT color, medications administered, route of administration (IV, intraosseous [IO], ET, etc.), and dose. Because we did not have a hospital weight against which to verify the documented prehospital weight, we compared the documented weight with the 5th to 95th percentile weight range for the patient's age from the CDC pediatric growth charts. Children with weights that far exceeded the 95th percentile or were far below the 5th percentile were excluded.

Data Analysis

We performed statistical analysis using Number Cruncher Statistical Software (NCSS, Inc., Kaysville, UT). Summary statistics were calculated for the data. Quantitative values were expressed as the mean ± standard deviation (SD), while nominal values were expressed as a percentage along with 95% confidence intervals (CIs). We calculated the magnitude of each dose error as a proportion of the correct weight- or BLT-based dosage. Documentation of BLT use and comparison of errors for patients with documented BLT use versus no documentation of BLT use were completed utilizing chi-square with significance set at <0.05. If the sample size was too small for the chi-square analysis, Fisher's exact test was used. Numbers of drug administrations by individual paramedics were tabulated.

RESULTS

For the study period, there were 267 patients aged ≤11 years who received drugs. These patients represented 2.5% of all pediatric (≤17 years) encounters and 0.16% of all EMS patient encounters for the study period. We excluded 23 (8.6%) patients for whom weight or BLT color was not reported, which prevented assessment of correct dosing. Analysis of patient weights for age versus the 5th to 95th percentiles from the CDC growth charts is shown in Figure 1. We excluded 14 (5.2%) patients whose weights fell far outside of the 5th and 95th percentile weights for age. This left 230

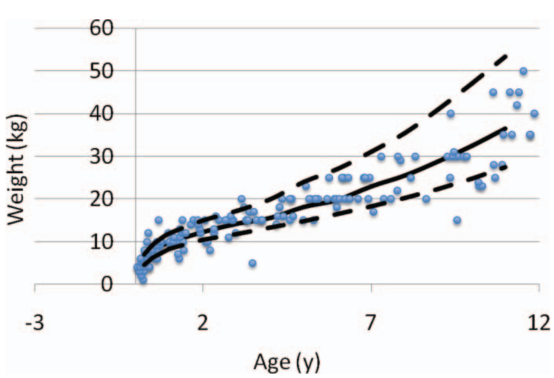

FIGURE 1. Analysis of documented patient weights versus Centers for Disease Control and Prevention (CDC) growth charts. The solid band represents the average between boys and girls for the 50th percentile. The upper dashed band represents the average between boys and girls for the 95th percentile. The lower dashed band represents the average between boys and girls for the 5th percentile.

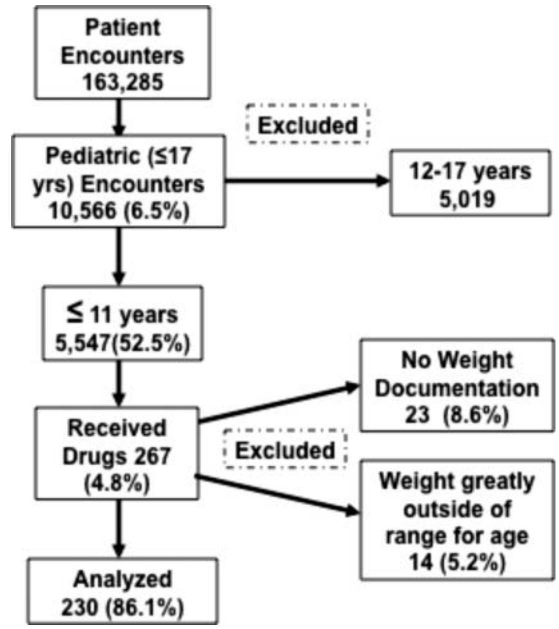

FIGURE 2. Patient enrollment.

patients in the final analysis. Patient enrollment is shown in Figure 2. Numbers of enrolled patients by age in whole years are shown in Figure 3. Children under 1 year of age represented the most common age group cared for (24%), while 8-year-olds were the least frequently cared for (2%). The percentages of patients receiving correct drug doses, stratified by patient age, are shown in Figure 4. Children less than 1 year of age and children aged 3 years had the highest percentages of incorrect doses (56% and 43%, respectively). Patient demographics are shown in Table 2. Paramedics administered medications 360 times to the 230 patients. Multiple drug doses were administered to 73 patients. Drug dosages were weight-based in 202 of 230 patients (87.8%) and BLT-based in 28 of 230 patients (12.2%). Twenty-six patients with BLT color documented also had a weight documented in the database.

During the 27-month study period, 132 of 425 (31.1%) paramedics administered a medication to a

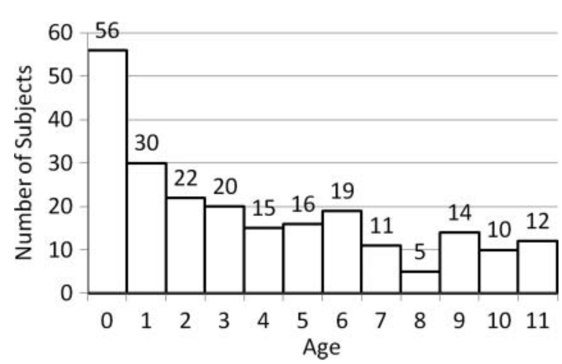

FIGURE 3. Number of enrolled patients by age in whole years. The number of patients for each year of age is shown above the bar.

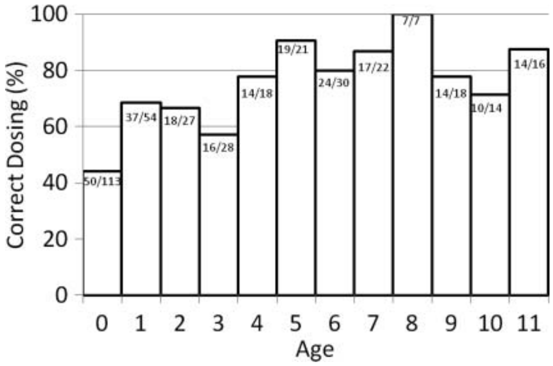

FIGURE 4. Percentage of correct medication dosing by patient age in whole years. Seventy-three patients had more than one dose administered.

patient ≤11 years old. The mean number of medications administered to patients ≤11 years old by an individual paramedic was 2.7 ± 2.4 (mean ± SD), with a range of 1–18.

Medication dosing errors occurred in 125 of 360 doses (34.7%; 95% CI 30.0, 39.8) (Table 3). Epinephrine had the highest percentage of incorrect doses. Incorrect doses of epinephrine by route and concentration are shown in Table 3. For atropine, the error frequency when BLT use was documented was significantly lower versus when BLT use was not documented (Table 4). This was not true for epinephrine. Only two doses of naloxone were administered, one correct dose with BLT use and one incorrect dose without BLT use.

DISCUSSION

Caring for patients in the prehospital environment is difficult, and potentially prone to medication errors. In our study of six prehospital medications commonly given to children, we observed drug dosage errors in more than a third of drug administrations. The magnitude of the dosing errors was as high as 808% of the correct dose as with intravenous/intraosseous 1:1000 epinephrine. Rough extrapolation of our findings from Michigan, based on 2000 U.S. census data, show that approximately 21,700 children aged 11 years and younger receive incorrect drug doses in the prehospital setting each year.

TABLE 2. Patient Demographics

Variable	Value
Age—mean ± SD, years	3.8 ± 3.5
Gender—male	160/228 (71.1%)*
Weight—mean ± SD, kg	20.3 ± 15.3
Ethnicity—white, non-Hispanic	117/223 (52.5%)*
Private insurance	87/228 (38.2%)*
Home/residence location	159/230 (69.1%)*

*The denominator is <230 because of missing data in those fields.
SD = standard deviation.

Few studies have characterized paramedic medication administration errors in children. In a cohort of cardiac arrest patients treated by Los Angeles County paramedics, Kaji et al. found that 56% of epinephrine doses were incorrect.[11] Lammers et al. found that 68% to 73% of epinephrine administrations by 212 paramedics during pediatric patient simulations were incorrect. They also found that the BLT was used incorrectly 47% of the time.[12] Our contrasting study evaluated five additional common pediatric medications. Our findings are important because epinephrine comprises a small fraction of medication administrations. Our study also included patients treated by multiple EMS agencies from noncontiguous counties throughout a state, instead of a single county, and thus the results may be more generalizable.

There are several potential explanations for the high prevalence of medication dosing errors in this study. A lack of paramedic pediatric clinical experience was evident in this study. Pediatric patients (≤11 years old) who received medications represented a very small fraction of all EMS patient encounters (0.16%). Only 31.1% of the paramedics studied administered a medication to a pediatric patient during the 27-month study period, and they did so infrequently. This is supported by prior research showing that paramedic encounters with pediatric patients are infrequent.[12,13,21] Encounters requiring advanced life support are even less frequent.[13] Such relative inexperience has been cited previously as a contributing factor to error.[22–24]

Faced with lack of real-life experience, paramedics rely on continuing education and training for most of their pediatric knowledge and skills.[25] The need for recurrent pediatric training is further supported by a study demonstrating knowledge decay to baseline levels just six months after paramedics completed an intensive pediatric resuscitation course.[26] Over a decade ago, improvement in pediatric training for paramedics was called for, with the recommendation that "review of all assessment and technical skills necessary for the management of a critically ill child be reviewed annually."[27] However, the suggested national paramedic pediatric continuing education training requirements are a maximum of three to four hours per year.[28] In a national survey, paramedics have reported receiving eight hours or less of pediatric-specific training in a two-year period.[29,30] Yet, the majority of paramedics in a 2005 survey supported increasing pediatric continuing education to ≥9 hours per year.[29]

Calculation errors appeared to play a role as well. This is supported by previous studies that have shown high error frequencies among resident physicians and paramedics when calculating pediatric medication doses.[31–36] This is especially true in stressful situations.[37] The lowest percentage of dosing error was for albuterol, which required no calculation. Medications that required any calculation had a much higher

TABLE 3. Incorrect Medication Doses, Overdoses, and Underdoses

Drug	No. Incorrect Doses/Total Doses	% Incorrect Doses (95% CI)	No. Overdoses	Overdose Mean Error (% ± SD)	No. Underdoses	Underdose Mean Error (% ± SD)
Albuterol	55/236	23.3% (18.4, 29.1)	1	200*	54	48.4 ± 8.8
Atropine	20/41	48.8% (34.3, 63.5)	8	407 ± 277	12	46.8 ± 15.0
Dextrose	2/4	50.0% (15.0, 85.0)	1	200*	1	62.5*
Diphenhydramine	7/13	53.8% (29.1, 76.8)	4	190.8 ± 45.3	3	53.3 ± 16.3
Epinephrine (1:1,000)	28/43	65.1% (50.2, 77.6)	6	655 ± 418	22	29.9 ± 22.4
Intravenous/intraosseus	13/25	52.0% (33.5, 70.0)	4	808 ± 428	9	35.5 ± 27.4
Endotracheal	14/14	100.0% (78.5, 100.0)	2	200, 500*	12	22.8 ± 14.7
Intramuscular	1/4	25.0% (4.6, 69.9)	0	—	1	65.2*
Epinephrine (1:10,000)	12/21	57.1% (36.5, 75.5)	2	167, 500*	10	13.8 ± 5.3
Intravenous/intraosseus	11/20	55.0% (34.2, 74.2)	1	167*	10	13.8 ± 5.3
Endotracheal	1/1	100.0% (20.7, 100.0)	1	500*	0	—
Naloxone	1/2	50.0% (9.5, 90.5)	0	—	1	25.0*

*Actual values; the mean and standard deviation were not calculated because of small sample size.
SD = standard deviation.

error frequency, such as with epinephrine and dextrose. Despite albuterol's having a standard dose for all patient weights, there still were a number of underdosing errors. We surmise that paramedics may have thought that the premeasured vial of albuterol represented an adult dose and therefore felt they should administer less to a child. Frequency of administration may also play a role. Albuterol was the most frequently administered drug and had the lowest percentage of incorrect doses. Dextrose, one of the least frequently administered medications, also requires the most complex calculation to determine the dose. It is intuitive that any individual who does not perform this calculation regularly would be prone to error.[22,23]

The lack of utilization of dosing aids, such as the BLT or weight-specific dosing cards that give drug doses in milliliters, thereby eliminating calculations, may have contributed to errors. Previous studies demonstrate that mathematical calculations of pediatric medication doses by paramedics and other health care providers are prone to error and paramedics frequently err at making weight estimations for pediatric patients. Given this information, one would expect the BLT to be utilized as a dosing aid.[31–36,38] Vilke et al. surveyed paramedics in San Diego County, California, and found that 74% reported using the BLT to determine every pediatric medication calculation, which differs from our data.[39] However, our findings are consistent with the pediatric simulation study by Lammers et al., who documented lack of BLT use in 50% of cases and incorrect use of the BLT in 47% of cases.[12]

Our study showed a significantly lower frequency of dose errors for atropine when BLT use was documented versus when it was not. The opposite was true for epinephrine; however, this did not reach statistical significance. The small number of patients with documented BLT use and the lack of direct observation of its use limit further analysis, and further investigation is warranted given these findings.

Our study highlights the absence of medication safety systems in the prehospital environment. In the hospital setting, multiple systems are present to safeguard and prevent medication administration errors. For example, computerized order entry, nurse and pharmacist checks of medication doses, and bar coding of medications all aid in intercepting errors. However, these safeguards are not available in the prehospital environment. Many prehospital scenarios also include time-sensitive and urgent situations with minimal personnel, where verification of dosages may not be practical.

Our study suggests potential solutions. Albuterol, the only medication in our study that had the same dose for all patient weights, had a much lower error frequency. Using a set dose across a range of weights instead of calculating doses for each pediatric patient could lead to fewer errors, yet may not always be practical. The BLT serves this function and represents a potential safety system for the prehospital environment. Increased and correct use of the BLT could lower error frequency, as demonstrated by Kaji et al.[11] Likewise, information cards with drug doses in milliliters for

TABLE 4. Incorrect Dosing Related to Documentation of Broselow-Luten Tape Use

	Broselow-Luten Tape Use Documented		Broselow-Luten Tape Use Not Documented		
Drug	No. Incorrect/Total	95% CI	No. Incorrect/Total	95% CI	p-Value
Atropine	10/27 (37.0%)	18.8, 53.3	10/14 (71.4%)	45.4, 88.3	0.04
Epinephrine*	31/46 (67.4%)	53.8, 80.9	9/18 (50.0%)	28.9, 71.1	0.20

*Epinephrine includes intravenous, intramuscular, and endotracheal routes.
Note: No patient with Broselow-Luten tape use documented received dextrose. Albuterol and diphenhydramine are not listed on the Broselow-Luten tape.
CI = confidence interval.

specific patient weights, which eliminate calculations, have been shown to decrease dosing errors by emergency medical technicians–paramedic (EMT-Ps).[40]

Increasing pediatric training requirements and practice could potentially decrease errors by giving paramedics more frequent exposure. In our study, children less than 1 year of age represented the most frequently encountered age group, yet they had the highest error incidence. Even though this age group was encountered most frequently, they represent just 1.0% of children 11 years and under and just 0.03% of all EMS encounters, adult and pediatric. Minimum experience standards for pediatric patient care, as a combination of actual patient encounters and training/simulation scenarios, may decrease errors. Such standards have been suggested for paramedic ET intubation.[41] Finally, although the EMS protocols utilized by paramedics in this study were developed by national consensus, they may not reflect the difficulty of administering medications in the field and reducing the variability of dosing.

Limitations

Our study has several limitations. This study is limited by its lack of actual observations and its use of an administrative data set. However, generating a high number of pediatric patient encounters via direct observation would be exceptionally difficult because of the low frequency of pediatric EMS encounters. Likewise, chart reviews on our sample, which covered a large geographic area, multiple hospitals, and eight EMS agencies, would have required a large number of person-hours as well as funding. Our study allowed us to efficiently get a first look at the prevalence of dosing errors across multiple EMS systems. Our findings are consistent with studies of different methodologies (chart review and simulation) examining this issue.[11,12] Our lack of direct observation does not allow us to know whether any of the paramedics utilized a dosing aid other than the BLT or whether they used the BLT but did not document it. It is possible that patients with weights documented in the prehospital record had this weight obtained via the BLT. If this was the case and the weight was correct, this would decrease the error prevalence associated with BLT use. A correct patient weight is necessary for correct medication dosing. We did not observe how weights were obtained or obtain a patient's hospital weight to compare with the prehospital record weight. However, we did compare the recorded weight with the expected weight for age on the CDC growth charts and found these to be reasonable. Prehospital providers do not have access to scales and therefore must rely on their own estimates, the BLT, or parents' reports. This reflects the real-world issue of obtaining a pediatric weight for EMS providers. Therefore, we made the assumption that the medication doses were based on the weight recorded in MERMaID. If drug doses were not based on the weight in MERMaID, this could increase or decrease the error frequency. The percentage of patients with missing weights (8.6%) is concerning. It is unknown why this occurred and whether this represents the weight's not being obtained at all or the weight's simply not being entered in the database. At the time of the study, the database did not contain a forcing function requiring weight to be entered in order to complete the patient record. This has since been rectified.

It is possible that some errors were due to incorrect data entry, with the patient's having been given the correct dose. It is also possible that patients without documented weights and/or BLT color did have correct weights and received the correct medication doses. Both of the aforementioned scenarios would decrease error frequency. The MMPP we used to define correct medication doses did not define "pediatric." A specific definition of pediatric (e.g., <9 years) might have resulted in fewer incorrect doses if paramedics gave a standard adult dose for patients outside of this age range. Furthermore, our data set from a specific geographic region may not reflect what happens outside of Michigan.

Grading medical errors has two components: 1) determining whether an error occurred and 2) determining whether the error caused harm. Since we did not have access to hospital records, we were unable to grade for harm. Some errors in this study were not likely to be clinically significant, and we did not determine why errors occurred.

Conclusions

Medications delivered to children in the prehospital setting by paramedics were frequently administered at doses outside of the proper range when compared with documented patient weights. EMS systems should develop strategies to reduce pediatric medication dosing errors.

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